Seabed Variability and its Influence on Acoustic Prediction Uncertainty

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LONG TERM GOALS

The long term goal is to assess and characterize uncertainty in the tactical naval environment. The focus is on the contribution of seabed variability to uncertainty in sonar performance predictions. In littoral warfare, the seabed is often a controlling factor in sonar system performance.

OBJECTIVES

The specific objectives of this effort are to characterize the spatial variability of the seabed geoacoustic properties using remote acoustic methods and determine the uncertainties and errors associated with the estimation of the geoacoustic properties.

APPROACH

Acoustic interaction with the seafloor often dominates and controls shallow water propagation and reverberation. Yet despite the availability of high-fidelity models, performance predictions may have large error bars because the seafloor geoacoustic data required drive the models have large uncertainties. The impact of seabed variability on sonar performance can be studied by analyzing the fundamental acoustic parameters that control seabed interaction: the seabed reflection coefficient and scattering strength. These two quantities allow a study of seafloor variability, nearly independent of oceanographic variability.

Many existing shallow water reflection and scattering measurement techniques spatially average over tens of km and thus are not well-suited for studying variability. Recently developed local measurement techniques for reflection (Holland and Osler, 2000) and scattering (Holland et al., 2000) are uniquely suited for probing spatial variability in shallow water. By measuring over a small footprint, of order 100m, spatial variability (both in the vertical and horizontal) can be probed to a much higher resolution. In addition, problems of intermingled geoacoustic variability with spatial-temporal oceanographic variability in long-range measurements are greatly diminished because of the short distances and the short time interval over which the local measurements occur.

The approach this year was to process and analyze reflection data at several key sites on the New Jersey Shelf (collected during Boundary Characterization 2001 Experiment) and reflection data at several key sites on the Tuscany Shelf and Malta Plateau. Sediment geoacoustic properties are

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14. ABSTRACT
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15. SUBJECT TERMS

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obtained from the processed reflection data in the time and frequency domain from a multi-stage inversion technique (Holland and Osler, 2000).

WORK COMPLETED

Broadband seafloor reflection data were processed at Sites 2,4,5,6, on the New Jersey shelf (see Fig 1) and the data were analyzed to obtain geoacoustic properties (sediment sound speed, density, and attenuation as a function of depth and frequency) of the seabed (Fig 2).

Data were also processed and analyzed from two regions in the Mediterranean Sea (the Tuscany shelf and the Malta Plateau) to obtain seabed reflection coefficients and scattering strengths. The variability in the reflectivity, scattering strength, and underlying geoacoustic properties of each region was determined separately. The analysis then considered the inter-regional variability with the surprising result that although the variability within a given region was quite large, the acoustic and geoacoustic character of the two sites were quite similar even though they separated by of order 1000 km.

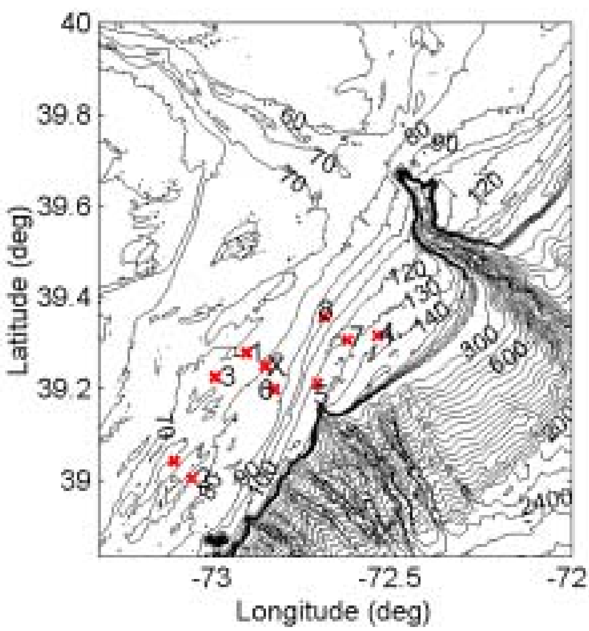

Figure 1. Location of seabed reflection and scattering sites in the STRATAFORM area (x). Depths are in meters.

RESULTS

The sediment sound speed spatial variability in the relatively small region of the New Jersey shelf is extremely large. Figure 2 shows the processed sediment sound speed profiles on the along with a comparison with the expected worldwide sound speed variability (Fig 2b). The observed variability within this small region is approximately 90% of that predicted by Hamilton (1980) for unconsolidated sediments worldwide. While it is common wisdom that shallow water variability is large, this research is helping to quantify that variability. How this geoacoustic variability translates into acoustic variability will be examined by other members of the DRI. The uncertainty in the sound speed estimates have not been fully established, but interim estimates are ± 5 m/s for the surficial values and ± 15 m/s for sub-bottom layers.

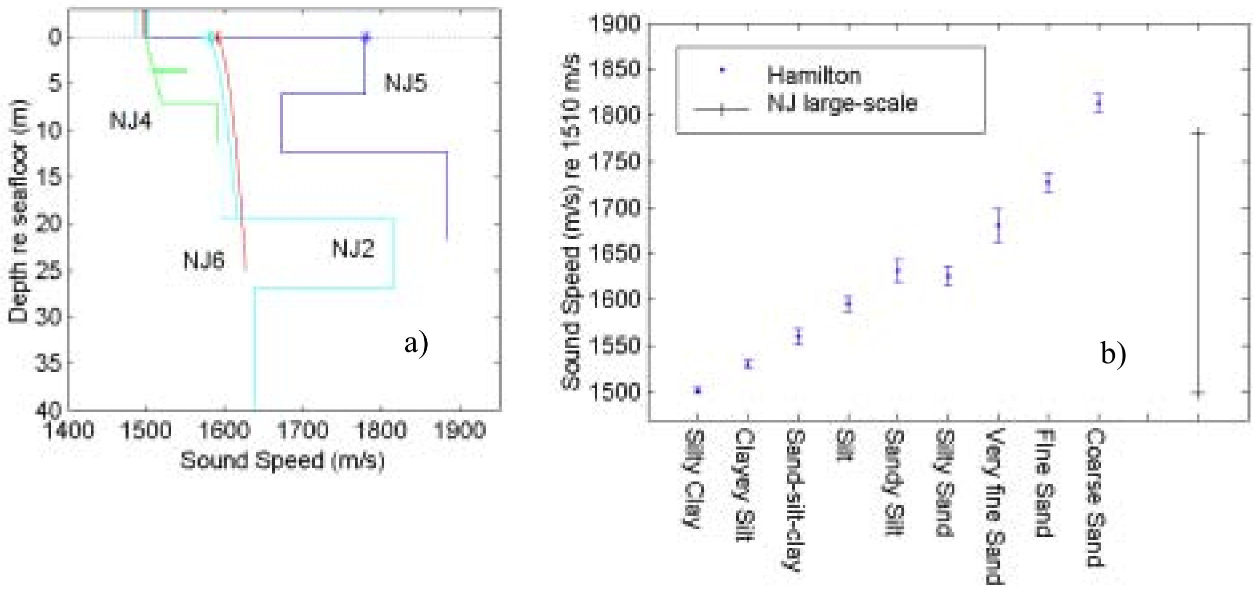

Figure 2. Sediment sound speed variability in the STRATAFORM area; a) variability at various sites (see Fig 1 for locations); b) comparison of the observed surficial velocity variability with that from Hamilton (1980) for continental shelves.

Another important issue addressed in this research was geoacoustic extrapolation, i.e., how do geoacoustic properties vary across very large scales, e.g., hundreds or thousands of kilometers? This answer to this question is important because it provides the foundation for determining if and how geoacoustic properties can be extrapolated over large regions. This issue was addressed via a measurements-based approach. Two study regions were selected with extensive acosutic, geoacoustic, and geophysical data: one on the Tuscany shelf and one on the Malta Plateau (Straits of Sicily). Each region has dimensions of order 50x50 km and the regions are separated by ~800 km.

Broadband seabed reflection loss (dB quantity of the reflection coefficient) analyzed at several sites gave insight into the variability of the sediment geoacoustic properties. Within a region the variability was described by geoacoustic regimes, sediment classes, and sedimentary features. The predominant regime in both regions is characterized by a mud host material with a sound speed gradient larger than Hamilton (1980) would predict and thin intercalating layers of sand mixed with shell and coral fragments. In this regime, the variability in layer geometry appears to have a minor effect on the acoustic response (i.e., reflection and scattering) of the seabed, simplifying the level of detail required for sonar performance prediction requirements. Each region showed two other identifiable regimes: the first being distinguished by a thick silty-clay layer and the second by sand over a consolidated basement.

Both regions show large variability in geoacoustic properties: on the Tuscany shelf, 5 sites showed 65% of the worldwide variability predicted by Hamilton; on the Malta Plateau 8 sites showed 95% of the worldwide variability. What was surprising, however, were the remarkable similarities observed between the two regions. The surficial silty-clay sediment is uniform across large areas of each region and has almost identical properties between the two regions, though the regions are separated by ~800 km. The similarities between the two regions go deeper. Each region has a similar layering structure (mud host with intercalating sandy-shelly layers, see Fig 3) and concomitant reflection characteristics over a broad part of the region (see Fig 4). Each region also has a broad area around the 100 m depth contour where the surficial silty-clay layer deepens to O(10) m in thickness. Significant differences in reflectivity were observed between the two regions at about the 130 m depth contour. Nearby core and seismic data suggest that the two regions are similar at these water depths, but that in the Malta Plateau, the reflection measurement sampled a feature (i.e., buried river channel) rather than the predominant regime.

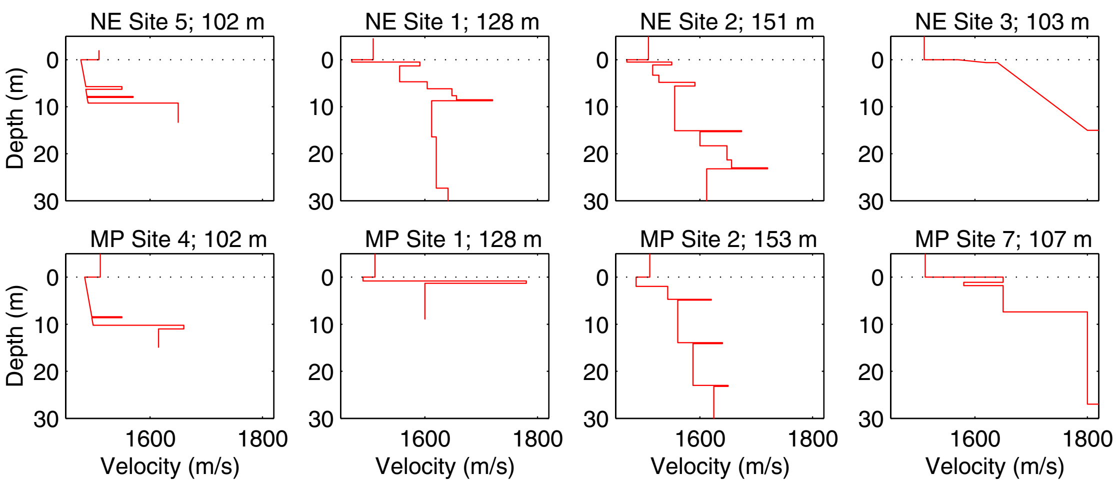

Figure 3. Sediment sound speed variability on the Tuscany Shelf (NE) and the Malta Plateau (MP).

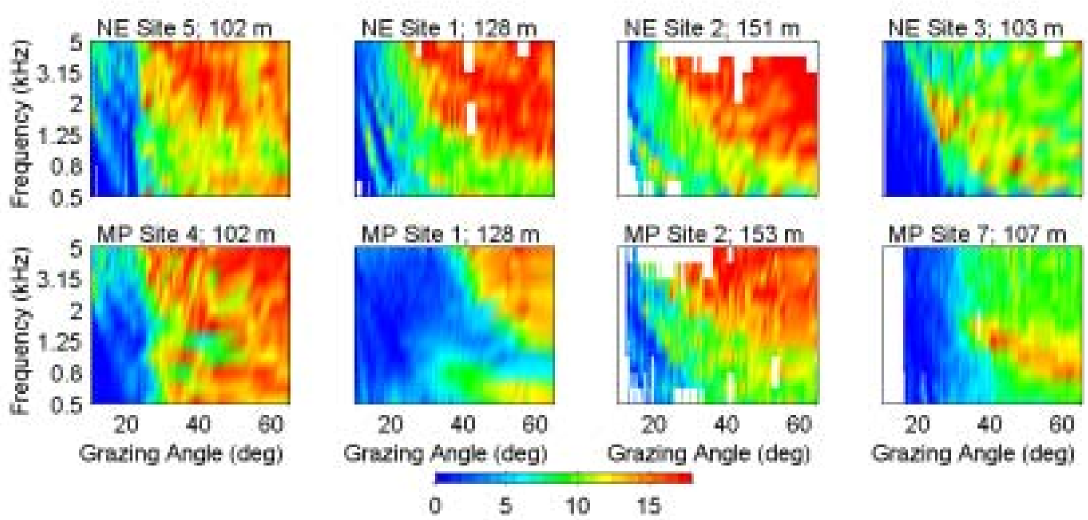

Figure 4. Seabed reflection loss (dB) variability on the Tuscany Shelf (NE) and the Malta Plateau (MP)

IMPACT/APPLICATIONS

New geoacoustic analysis techniques are being developed and applied to reflection and scattering data sets in order to probe the spatial variability and uncertainty associated with seabed properties. The results will be compared and fused with other researchers in the Seabed Variability team (Syvitski, Pratson, Goff, and Mayer) and others both within and without the Uncertainty DRI in order to obtain the highest resolution and widest coverage of the geoacoustic spatial variability. The resulting geoacoustic variability will be employed by propagation/reverberation modelers (Odom, LePage, and Harrison with the Seabed Variability Team and others external to the team) to determine the concomitant uncertainty in sonar performance.

The inter-regional similarities raise numerous questions: are these inter-regional similarities expected around the entire littoral Italian zone? Are these inter-regional similarities predictable and if so, at which level: the geoacoustic regimes? their boundaries? sediment classes? These questions are important because acoustic models will always be faced with insufficient geoacoustic data. The ability to extrapolate geoacoustic measurements from region-to-region could provide an important advance for sonar performance prediction. Geologic/geophysical models, e.g., Syvitski et al.(1999) may provide the framework for addressing many of these issues.

RELATED PROJECTS

ONR GeoClutter: Providing high resolution acoustic and geoacoustic data required for estimating seabed spatial variability and uncertainty on the New Jersey shelf.

Boundary Characterization Joint Research Project ONR-NATO SACLANT Centre: Providing high resolution acoustic and geoacoustic data required for estimating seabed spatial variability and uncertainty estimates in the Straits of Sicily and the Tuscany Shelf.

ONR SWAT Program: Collaborating on geoacoustic findings on the New Jersey Shelf.

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